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SOME PROBLEMS IN FLANGING AND BEADING MEMBRANES

By B. V. Grigoryev

Translated from "Some Questions Pertaining to Modern
Instrumentation Technology," edited by Poliakov

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SOME PROBLEMS IN FLANGING AND BEADING MEMBRANES*

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The press chambers widely used for hydraulically flanging and beading membranes are chambers with screw or gun-breech blocks (Fig. 1). These cham-

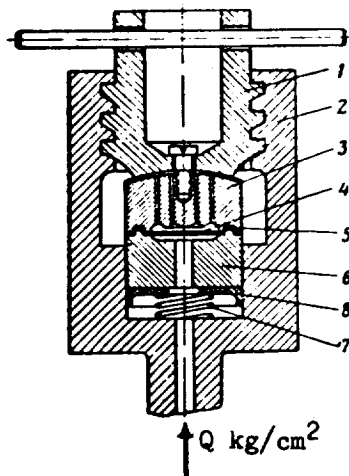


Fig. 1. Hydraulic chamber.

bers consist of a body 2 with a block 1 and a die 3 attached to it. In the chamber is located plunger 6 with cup 8 attached to it, both of which rest on spring 7. Membrane blank 4 is placed in the cavity of the plunger and is pressed slightly against the annular projection of the die, a large part of the stress of which goes into stamping out sealing ridge 5, which guarantees that the chamber is hermetic. The liquid enters the chamber through a central channel in the direction of the arrow and performs two kinds of work; as the pressure increases it reinforces the stamping of the sealing ridge and, on the other hand, it effects the beading and flanging of the membrane from the blank.

The hydraulic method of beading may be used equally well for membranes of cold-worked materials and for materials which have undergone thermal treatment, to give them high elastic properties. The method of flanging and beading membranes which is under consideration gives considerably more stable properties and less residual deformations, elastic fatigue and hysteresis than membranes prepared by means of resin, lead, or steel stamps and dies.

But despite the advantages that have been referred to, even in the hydraulic method of corrugating membranes there still occurs instability of the properties, increased elastic fatigue and hysteresis, and sometimes even rupture of the membranes. In order to elucidate the causes for the appearance of

*Translated from "Some Questions Pertaining to Modern Instrumentation Technology," edited by Poliakov, pp. 84-96.

these defects, the process in question must be analyzed.

It is not possible in the present article to make a full analysis of the process up to the formation and distribution of the internal residual stresses in membranes, the irregularity of distribution and the magnitude of which are directly related to the residual deformation and the elastic fatigue. Accordingly, only those processes will be considered below that are connected with the pressure necessary for crimping, and with the reinforcement of the pressure of the blank against the rim. These two questions are especially important with respect to obtaining membranes of high quality.

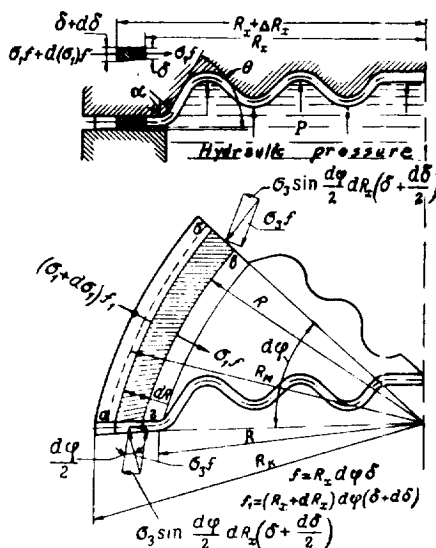


Fig. 2. Calculating crimping stress.

As we know, corrugation of the membranes is accompanied by a decrease in the outer diameter of the blank (disk). Consequently the rim of the membranes is subject to stresses in the process of corrugation. In order to exhibit the stressed condition of the edge of the membrane, we choose a sector (Fig. 2) with an angle $d\varphi$, and consider the condition for the equilibrium of an infinitely small element $abed$, which is under the stress of hydraulic pressure, which is applied in order to produce the corrugation.

This element is subjected to tensile stress σ_1 , to tangential compressive stress σ_3 and to compressive stress σ_2 , which arises from the pressure acting on the rim of the membrane.

At the initial motion of crimping, when there is the optimum amount of pressure on the disk, stress σ_2 is insignificant and may be ignored. Then, using the designations indicated in Fig. 2, the equilibrium conditions for element $abed$, may be easily defined, if we take into account all the forces acting on the element selected. A tensile force

$$-\sigma_1 f = -\sigma_1 \delta R_x d\varphi$$

acts on the element.

To the extent that the rim is under tensile stress, there appear compressing forces of tangential stresses $\sigma_3 f$, resolution of which makes it possible

to establish the components opposing the tensile stress, the sum of which is equal to

$$2\sigma_3 \sin \frac{d\varphi}{2} dR_x \left(\delta + \frac{d\delta}{2} \right)$$

Finally, there acts on the element a force opposing the retraction $(\sigma_1 + d\sigma_1)/2$, the magnitude of which is equal to

$$(\sigma_1 + d\sigma_1)(R_x + dR_x)d\varphi(\delta + d\delta)$$

Knowing the forces acting on the element, it is easy to set up the equation for its equilibrium

$$-\sigma_1 \delta R_x d\varphi + 2\sigma_3 \sin \frac{d\varphi}{2} dR_x \left(\delta + \frac{d\delta}{2} \right) + (\sigma_1 + d\sigma_1)(R_x + dR_x)d\varphi(\delta + d\delta) = 0 \quad (1)$$

Multiplying out and ignoring the terms of the third order of smallness, we may write

$$\sigma_1 + R_x d\varphi d\delta + 2\sigma_3 \sin \frac{d\varphi}{2} dR_x \delta + \sigma_1 dR_x d\varphi \delta + d\sigma_1 R_x d\varphi \delta = 0$$

In view of the smallness of angle $d\varphi$ we take $\sin \frac{d\varphi}{2} = \frac{d\varphi}{2}$ or $2 \frac{d\varphi}{2} = d\varphi$ and, dividing each term by $R_x d\varphi \delta$, we have

$$\sigma_1 \frac{d\delta}{\delta} + \sigma_3 \frac{dR_x}{R_x} + \sigma_1 \frac{dR_x}{R_x} + d\sigma_1 = 0$$

or

$$d\sigma_1 + \sigma_1 \frac{d\delta}{\delta} + (\sigma_1 + \sigma_3) \frac{dR_x}{R_x} = 0 \quad (2)$$

It is known from deformation theory that

$$\sigma_1 \pm \sigma_3 = 1.15 p_c \quad (X)$$

where p_c is the resistance to deformation in kg/mm^2 .

The sign in equation (X) is chosen according to the following condition: if the main stresses σ_1 and σ_3 are both tensile or compressive stresses, the sign will be minus, but if one of the main stresses is a tensile stress and the other a compressive stress, the sign will be plus.

Substituting from Equation (X) in Eq. (2) we have

$$d\sigma_1 + \sigma_1 \frac{d\delta}{\delta} + 1.15 p_c \frac{dR_x}{R_x} = 0 \quad (3)$$

Integrating Eq. (3) over the interval from R_x , assuming a maximum value as R_k to R , we have

$$\int_{R_k}^R d\sigma_1 + \frac{\sigma_1}{\delta} \int_{R_k}^R d\delta = -1.15 \int_{R_k}^R p_c \frac{dR_x}{R_x}$$

Here

$$\int_{R_k}^R d\sigma_1 = \sigma_{1cp}$$

describes the mean tensile strength in the interval from R_k to R , and

$$\frac{\sigma_1}{\delta} \int_{R_k}^R d\delta = \frac{\sigma_1}{\delta} \Delta\delta$$

represents the stress referred to the initial thickness, multiplied by the mean thickness $\Delta\delta$ in the interval from R_k to R . But since stress σ_1 relates to a portion of the rim from R_k to R , it is in essence σ_{1cp} , and consequently the equality of intervals may be presented in the form

$$\sigma_{1cp} + \sigma_{1cp} \frac{\Delta\delta}{\delta} = 1.15 \int_{R_k}^R p_c \frac{dR_x}{R_x}$$

or

$$\sigma_{1cp} \left(1 + \frac{\Delta\delta}{\delta}\right) = 1.15 \int_{R_k}^R p_c \frac{dR_x}{R_x}$$

from which

$$\sigma_{1cp} = \frac{1.15}{\left(1 + \frac{\Delta\delta}{\delta}\right)} p'_c (\lg R - \lg R_k) \quad (XX)$$

where p'_c is the mean value of the resistance to deformation over the width of the membrane rim at the corresponding moment of tension.

Designating $\frac{\Delta\delta}{\delta} = \lambda$, formula (XX) may be written in the form

$$\sigma_{1cp} = - \frac{1.15}{1 + \lambda} p'_c \lg \frac{R_k}{R} \quad (4)$$

Solving Eq. (X) and Eq. (4) simultaneously, we easily find the magnitude of the compression stress as

$$\sigma_3 = 1.15 p'_c \left(\lg \frac{R_k}{R} - 1 \right) \quad (XXX)$$

In Eqs. (4) and (XXX) R_k is the radius vector of the membrane, which changes from R_k to R , that is on the diameter of the disk to the diameter of the formed membrane, and R is the effective radius of the membrane. If in the equations above we designate $\frac{R_m}{R}$ as K , Eqs. (4) and (XXX) may be written in the form

$$\sigma_{1cp} = \frac{1.15}{1 + \lambda} p'_c \lg K \quad (5)$$

$$\sigma_3 = 1.15 p'_c \left(\lg K - 1 \right) \quad (XXXX)$$

To determine the stresses at any point of the membrane's rim in Eqs. (4) and (XXX), we must substitute for R the corresponding radius R_x , and in Eqs. (5) and (XXXX), correspondingly $\frac{R_m}{R_x} = K_x$.

However, the tensile and compression stresses determined according to Formulas (5) and (XXXX) do not take into account the supplementary stresses in the material induced by the superficial friction between the rim of the membrane

and the instrument. But since in the process of crimping of the membranes there is a superficial force of friction, which arises as a result of the contact of the rim (Fig. 3), its magnitude may be designated in the form

$$T = 1.5\mu Q$$

where μ - coefficient of friction;

Q - force with which rim of the membrane is pressed;

1.5 - coefficient which does not contemplate complete contact on both sides of the membrane rim with the tool, since as on one side contact of the rim with the tool usually is only 50% of the surface of the rim, which is explained by the pressing of the material almost at the very beginning of crimping of the membrane.

Knowing the force of friction T , it is easy to define the stress due to the forces of friction at the place where the rim goes over into the radius of the outermost corrugation of the membrane

$$\sigma_T = \frac{T}{2\pi R\delta} = \frac{1.5\mu Q}{2\pi R\delta} \quad (\text{XXXXX})$$

If we take as the specific pressure at which the surfaces are pressed together

$$q = \frac{Q}{\pi(R_M^2 - R^2)}$$

we have

$$Q = q\pi(R_M^2 - R^2)$$

Substituting this value in Eq. (XXXXX), we have

$$\sigma_T = \frac{1.5\mu q(R_M^2 - R^2)}{2R\delta} = 0.75 \frac{\mu q}{\delta} (K^2 - 1)R \quad (6)$$

where

$$K = \frac{R_M}{R}$$

Hence, in beading and flanging membranes the general specific stress of the tension of the rim, taking into account the effect of the frictional force, will be

$$\sigma_B = \sigma_{lcp} + \sigma_T = \frac{1.15}{1 + \lambda} p_c' \lg K + 0.75 \frac{\mu q}{\delta} (K^2 - 1)R \quad (7)$$

It will easily be seen from Eq. (7) that for constant values of λ ; p_c' ; K ; μ and q , as the ratio $\frac{R}{\delta}$ increases, the resistance to retraction increases; it likewise increases as the dimensions of the membrane rim increase, which is explained by the increase in the coefficient $K = \frac{R_M}{R}$ and consequently, has a negative effect on the corrugation process, preventing maximum extrusion of the corrugations.

Finally, it should be noted that Formula (7), which describes the magnitude of the stress of the retraction of the rim in hydraulic corrugation of membranes, contemplates optimum specific pressure against the disk, which, as will be visible, is not the case in the hydraulic method of corrugating membranes, not by any means, in view of the fact that the force of the pressure of the parts against each other Q rises continuously, in direct proportion to the hydraulic pressure in the chamber.

However, despite the instability of the magnitude of the specific force pressing against the blank, it is advantageous to continue to calculate on the assumption that $q = \text{const}$, and then introduce corresponding corrections into the results obtained.

Upon further consideration of the process, it will be seen that in the process of crimping membranes still another supplementary resistance to retraction arises, from the gradual curving of the material of the radius of the die at the place where the rim goes over into the outermost corrugation of the membrane.

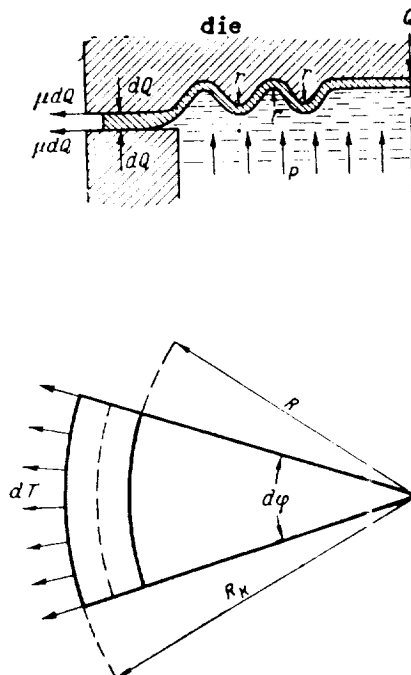


Fig. 3. Diagram of action of surface friction.

In this region the material is subject to a complex deformation comprising bending, dilatation and compression.

The size of the transitional radius from the rim to the outermost corrugation has an especially essential influence on the stresses in the material in a bending region.

The smaller the radius of curvature, the greater the stresses that will arise at the point of bending of the material, in particular the tensile stresses. The strains that take place and the stresses appearing in the region of curvature along the radius constitute an extremely complex process of corrugation of the membrane, and in practice this problem can only be solved more or less approximately, assuming that in the region of the radius of curvature the fibers of the material belonging to the die are elongated in proportion to the coefficient of extension

$$K_B = \frac{F_M}{F_k}$$

(where F_M is the surface of the membrane in mm^2 and F_k is the area of the disk in mm^2), and taking into account the circumstance that as the metal goes up around the curvature of the radius, the contact friction will more and more interfere with deformation of the fibers. In that way, the proportionality of the exten-

sion of the coefficient of elongation will as an average be expressed as $\frac{1 + K_B}{2}$.

In this case (Fig. 4) it may be assumed that an elementary portion of

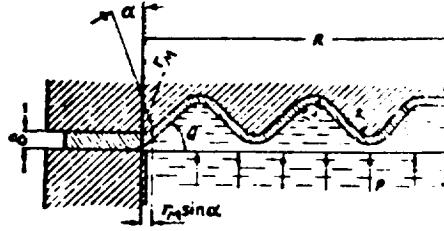


Fig. 4. For defining forces of friction on transitional radius r_M .

the curved length Δl , when transferred to the radius of curvature of the die, is elongated by

$$\frac{1}{2} \Delta l \left(\frac{r_M + \delta}{r_M + 0.5\delta} - \frac{r_M}{r_M + 0.5\delta} \right) \left(\frac{1 + K_B}{2} \right) = \Delta l \frac{\delta}{2r_M + \delta} \left(\frac{1 + K_B}{2} \right)$$

Setting as equal to each other the work of the external and internal forces accompanying the bending of the material of the blank (disk) along the radius of curvature of the die, we may write

$$P_{\text{bending}} \Delta l \approx 2\pi R \delta p_c'' \Delta l \frac{\delta}{2r_M + \delta} \left(\frac{1 + K_B}{2} \right)$$

from which the additional force for bending the material along the radius of curvature will be

$$P_{\text{bending}} = \frac{2\pi R \delta p_c''}{2r_M + \delta} \left(\frac{1 + K_B}{2} \right)$$

where p_c'' is the mean resistance of the material to deformation along the transition radius of curvature r_M in kg/mm^2 .

Knowing the bending force, it is easy to determine the stress arising from bending

$$\sigma_{\text{bending}} = \frac{P_{\text{bending}}}{2\pi(R - 2r_M \sin \alpha)\delta} = \frac{R \delta p_c'' (1 + K_B)}{2(2r_M + \delta)(R - 2r_M \sin \alpha)} \quad (8)$$

(for the symbols entering into the formula, see Fig. 4).

On the basis of Eqs. (7) and (8) we define the total stress on the transition radius of curvature from the rim to the outermost corrugation of the membrane

$$\sigma_{\Sigma}' = \sigma_B + \sigma_{\text{bending}} = \sigma_{\text{lcp}} + \sigma_{\tau} + \sigma_{\text{bending}}$$

This equation does not take into account the force of friction on the transition radius and the angle θ of the slope of the outermost corrugation of the membrane in Fig. 4, which at the point of contact of radius r_M will be equal to angle α and determinate.

Taking into account the friction at the transition radius of curvature

r_M , at angle $\alpha = \theta$, we may set up the following equation of definition:

$$\sigma_\Sigma = \left[(\sigma_{lcp} + \sigma_r) e^{\mu\alpha} + \sigma_{bending} \right] \sin \alpha$$

where μ - coefficient of friction;

α - angle of slope of the outermost corrugation; in the exponents it is given in radians;

$e^{\mu\alpha}$ - a factor which takes into account the frictional resistance at the transitional radius of curvature.

Consequently, the formula for the contractile stress σ_Σ at the point of contact of the rim with the outermost corrugation will have the following form, as expanded

$$\sigma_\Sigma = \left\{ \left[\frac{1.15}{1 + \lambda} p'_c \lg K + 0.75 \frac{\mu q}{\delta} (K^2 - 1) R \right] e^{\mu\alpha} + \frac{R \delta p''_c (1 + K_B)}{2(2r_M + \delta)(R - 2r_M \sin \alpha)} \right\} \sin \alpha \quad (9)$$

Knowing σ_Σ and taking into account the fact that corrugating the profile of the corrugations and the flat center of the membrane is accompanied by a thinning of the material, it is easy to define the required specific pressure necessary for hydraulic corrugation of the membranes according to the familiar formula for thin cylindrical membranes, according to which

$$p_{hyd} = \frac{\delta}{r'_M} \sigma_\Sigma \quad (10)$$

where r'_M is the smallest radius of curvature of the peaks or depressions on the corrugations; this radius is usually the radius of transition from the rim to the outermost corrugation.

To simplify the calculations for defining the contractile stress σ_Σ from Formula (9), the actual stresses of deformation p'_c and p''_c may be equated to the yield point σ_s of the material.

The yield point σ_s is easily determined under these circumstances from the familiar curves of the mechanical properties of the various materials, depending on the degree of deformation*

In this way, we may take

$$p'_c \approx p''_c \approx \sigma_s$$

Below is a test of the Formula (9) derived in an example of calculating the specific hydraulic pressure for crimping a membrane of phosphor bronze BrOPh 6.5-04, for total degree of deformation equal to 30%, the ultimate strength of the bronze being $\sigma_b = 50 \text{ kg/mm}^2 \approx p'_c \approx p''_c$.

If the parameters of the membrane are

$$R_k = 30 \text{ mm} \quad \delta = 0.3 \text{ mm}$$

$$R = 25 \text{ mm} \quad \frac{F_M}{F_k} = K_B = 1.3$$

$$\frac{R_k}{R} = K = 1.2 \quad r_M = 0.5 \text{ mm}$$

* A. P. Smiryagin, Industrial nonferrous metals and alloys, Metallurgizdat, 1949.

$$\begin{aligned}\frac{\Delta\delta}{\delta} &= 0.1 & \alpha &= 45^\circ \\ e^{\mu\alpha} &= 1.12 & \theta &= 45^\circ \\ \mu &= 0.2 \text{ kg/mm}^2 & \delta_M &= \frac{\delta}{1.3} \text{ mm}\end{aligned}$$

On the basis of Formula (5)

$$\sigma_{1cp} = \frac{1.15}{1 + \lambda} p'_c \lg K = \frac{1.15}{1 + 0.1} 50 \lg 1.2 \approx 5.8 \text{ kg/mm}^2$$

On the basis of Formula (6)

$$\sigma_T = 0.75 \frac{\mu q}{\delta} (K^2 - 1) R = 0.75 \frac{0.25 \times 0.2}{0.3} 0.44 \times 25 \approx 1.37 \text{ kg/mm}^2$$

On the basis of Formula (8)

$$\begin{aligned}\sigma_{\text{bending}} &= \frac{R \delta_p'' (1 + K_B)}{2(2r_M + \delta)(R - 2r_M \sin \alpha)} \\ &= \frac{25 \times 0.3 \times 50 \times 2.3}{2(2 \times 0.5 + 0.3)(25 - 2 \times 0.5 \times 0.707)} = 13.7 \text{ kg/mm}^2\end{aligned}$$

On the basis of Formula (9)

$$\begin{aligned}\sigma_\Sigma &= [(\sigma_{1cp} + \sigma_T) e^{\mu\alpha} + \sigma_{\text{bending}}] \sin \alpha \\ &= [(5.8 + 1.37) 1.12 + 13.7] 0.707 = 15.36 \text{ kg/mm}^2\end{aligned}$$

Knowing the quantity σ_Σ , it is easy to determine, from Formula (10), the pressure in the chamber that will be necessary for corrugation.

$$p'_{\text{hyd}} = \frac{\delta}{r_M} \sigma_\Sigma = \frac{0.3}{0.5} 15.36 \approx 9.21 \text{ kg/mm}^2 \text{ (or 921 atm)}$$

This account of the amount of pressure necessary for corrugation would be completely justified under the condition of constancy of surface pressure against the blank or, what comes to the same thing, with a specific force of surface pressure $q = \text{const}$, the magnitude of which, in order to make sure of the qualitative process of extrusion of the membrane of rolled bronze is recommended to be kept within the limits $q = 0.2-0.25 \text{ kg/mm}^2$, and for steel $q = 0.25-0.4 \text{ kg/mm}^2$.

However, in the hydraulic chambers employed in practice, it is not possible to produce an operating pressure in the corrugating operation with a completely definite limiting pressure at the rim of the membrane, since the magnitude of this pressure, as the liquid is added to Chamber A of the press (Fig. 5) with increasing pressure, continuously increases the contact pressure of the blank in proportion to the pressure of the liquid.

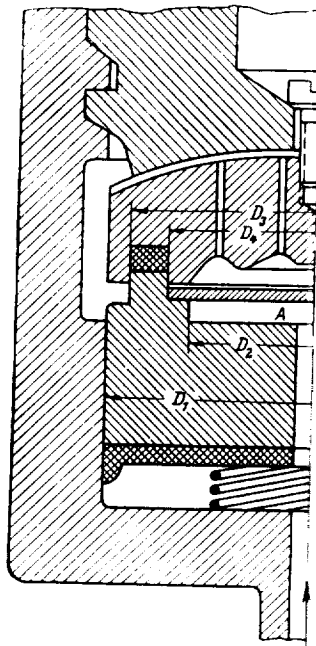


Fig. 5. For calculating surface pressure on blank.

The pressure against the blank in hydraulic chambers takes place in the following way.

1. After the blank (disk) has been placed in the chamber and the chamber has been closed with the block, the blank is not pressed down or at best it is pressed down with the weight close to the portion of the force of the spring, not greater than βQ_n , whereas the force of the lock acts basically to press down the sealing gasket and this gives the coefficient

$$\beta = \frac{D_4^2 - D_2^2}{D_3^2 - D_2^2}$$

Hence, the maximum limiting pressure against the blank before beginning the corrugation will be

$$q_0 = \frac{4\beta Q_n}{\pi(D_3^2 - D_2^2)}$$

Taking, in Fig. 5 $D_4 = 60$ mm, $D_1 = 80$ mm, $D_2 = 50$ mm, $D_3 = 68$ mm and $Q_n = 10$ kg, we have

$$q_0 = \frac{4Q_n \left(\frac{D_4^2 - D_2^2}{D_3^2 - D_2^2} \right)}{\pi(D_3^2 - D_2^2)} = \frac{4Q_n (D_4^2 - D_2^2)^2}{\pi(D_3^2 - D_2^2)^2} = \frac{4 \times 10(60^2 - 50^2)}{3.14(68^2 - 50^2)^2} \approx 0.0003 \text{ kg/mm}^2$$

2. As the liquid is admitted to the chamber under pressure, there is further pressure on the gasket and the limiting pressure against the rim of the blank rises, attaining the normal, that is the recommended limiting pressure $q = 0.2 \text{ kg/mm}^2$ when the hydraulic pressure in the chamber is

$$p = \frac{D_3^2 - D_2^2}{D_1^2 - D_2^2} q = \frac{68^2 - 50^2}{80^2 - 50^2} 0.2 \approx 0.108 \text{ kg/mm}^2 \text{ (or 10.8 atm)}$$

3. As the hydraulic pressure of the liquid in the chamber, calculated from Formula (10), increases, the limiting pressure against the surface of the blank increases, amounting to

$$q_2 = \frac{4(D_1^2 - D_2^2)p_{\text{hyd}}}{\pi(D_3^2 - D_2^2)^2}$$

This figure for the limiting pressure comes to, for the present example,

$$q_2 = \frac{4(8^2 - 5^2) \times 921}{3.14(6.8^2 - 5^2)^2} = \frac{143,676}{1416} = 100 \text{ atm (or 1 kg/mm}^2\text{)}$$

If we also take into account the decrease of the loaded diameter of the membrane upon corrugation, which occurs in the initial period of the corrugation and is expressed in the decrease of the width of the rim $\frac{k}{2}$, roughly 10%, then the limiting value for the pressure on the face will rise to

$$q_{2 \text{ max}} = 1.06 \text{ kg/mm}^2$$

It will be seen that $q_{2 \text{ max}}$ is several times larger than the permissible magnitude $q = 0.2\text{--}0.25 \text{ kg/mm}^2$ for bronze and $q = 0.25\text{--}0.4 \text{ kg/mm}^2$ for steel.

This difference between the permissible and the actual limiting pressures obtained at the end of the crimping process, complicates the formation of the corrugations and causes pressure of the liquid in the chamber to be used that is considerably higher than that defined by Formula (10), by way of correction in Formula (6), which enters into Formula (9) which determines the quantity σ_Σ .

Thus, for instance, from Formula (6) we have for the example taken

$$\sigma_\tau = 0.75 \frac{\mu q_{\text{max}}}{\delta} (K^2 - 1)R = 0.75 \frac{0.25 \times 1.06}{0.3} \times 0.44 \times 25 = 7.32 \text{ kg/mm}^2$$

and from Formula (9)

$$\begin{aligned} \sigma_{\Sigma \text{ max}} &= \left[(\sigma_{\text{lcp}} + \sigma_\tau) e^{\mu \alpha} + \sigma_{\text{bending}} \right] \sin \alpha \\ &= [5.8 + 7.32] 1.12 + 13.7 \approx 20 \text{ kg/mm}^2 \end{aligned}$$

Inserting this value in Formula (10) we have

$$p_{\text{hyd}}'' = \frac{\delta}{r_M} \sigma_{\Sigma \text{ max}} = \frac{0.3}{0.5} \times 20 = 12 \text{ kg/mm}^2$$

or 1200 atm instead of 921 atm, the figure obtained for the normal limiting pressure against the face of the blank in hydraulic fluting of the membrane

with the parameters given in the present example.

In turn, increasing the pressure in the chamber by $1200-921 = 279$ atm increases the limiting pressure against the surface, which could be calculated, but there is no need for it, since at the end of corrugation the thickness of the membrane is no longer equal to δ , but on the average to

$$\delta_M = \frac{\delta}{K} = \delta : \frac{F_M}{F_K}$$

and in our example, with $K = \frac{1}{3}$,

$$\delta_M = \frac{0.3}{1.3} \approx 0.23 \text{ mm}$$

Inserting this value for δ_M in Formula (10), we have

$$p_{hyd} = \frac{\delta_M}{r_M} \sigma_{\Sigma max} = \frac{0.23}{0.5} \times 20 = 9.20 \text{ kg/mm}^2$$

or 920 atm, a little less than $p'_{hyd} = 921$ atm and consequently, there is no need actually to calculate the increased limiting pressure against the blank, which would be necessary if $p_{hyd} > p'_{hyd}$.

Further, it must be stressed that the rise in the pressure p''_{hyd} of the liquid in the chamber by $1200-921 = 279$ atm, is only necessary because of the imperfections in the system of pressing on the blank, so that it cannot be insured that $q = \text{const}$. In addition, the pressure on the blank in the chambers that are in use cannot guarantee an equal pressure, but even if a joint of this kind could be produced, even then one-sided pressure against the blank would be possible because of variations in the thickness of the membrane blanks.

Hence, it is inevitable that cases of one-sided pressure against the blanks should occur, and therefore the formation of elliptical membranes with residual internal stresses that are asymmetrically situated with respect to the axis of flexure and varying in magnitude. This phenomenon leads to a considerable dispersion of the characteristic curve, a high residual deformation, and high elastic fatigue. In order to eliminate this defect in the hydraulic chambers in use, Engineer G. N. Frolov (NIAT) composed a new system of pressing against the blanks in hydraulic chambers (Fig. 6). The distinguishing feature of this design is the separation of the pressure of the blank against the die and the pressure on an annular contact, without gasket, along the recess in die 3 and the projection of plunger 6, designed to insure a hermetic seal in the chamber.

In this design, the initial force of contact of the annular depression between the die and the plunger is regulated by regulating support 11, which slides in base 13 and is set by pin 12, and the necessary initial clearance between the pressure surfaces of the membrane with a definite force are set by means of threaded support 5, on which crimpholder 4 is based, while the force of pressure on the hollow and the projection of the annular contact may be extremely high.

One advantage of this design is that crimpholder 4, which is up against the spherical surface of support 5, insures an even pressure against the rim of the blank. Furthermore, in this design it is impossible to set up excessively large forces for pressure against the blank, since in this case the annular contact between the groove in the die and the projection in the plunger will not be able to insure a hermetic seal and there will be play between them, through which space the liquid will force its way and the pressure in the chamber will drop.

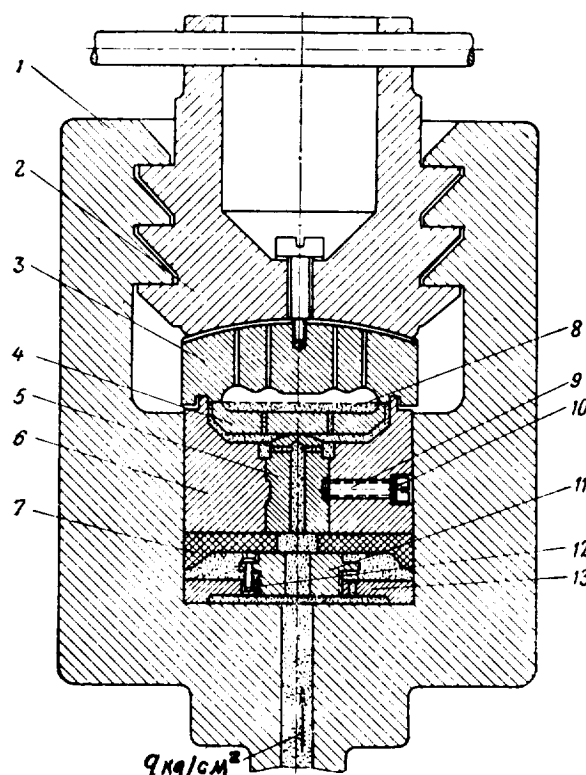


Fig. 6. Diagram of hydraulic chamber with perfected surface pressure.

1 - body, 2 - lock, 3 - die, 4 - crimpholder, 5 - support, 6 - plunger,
7 - cup, 8 - blank, 9 - screw, 10 - packer, 11 - support, 12 - pin,
13 - base

However, despite the advantages of this method of preparing the blank in hydraulic chambers, an apparatus for optimum contact pressure is a complicated one, and hence further perfection of hydraulic chambers is of the first necessity.

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